Abusive Slam on a Car Hood

Robert Engberg
Summary

This degree project was conducted at Saab Automobile AB with focus on abusive slam on a car hood. It resulted in a definition and a requirement for an abusive slam, an evaluation and modification of the test procedure and a set of measurement files for correlation with the simulation models.

A customer related definition for an abusive slam has not existed at Saab. Therefore hood closing clinics and a literature study on hood closures, on customer cars, were conducted. The information gathered generated a definition for abusive slam:

*Abusive slam is defined as a closing of the hood with a critical closing velocity. The critical closing velocity is proposed to be 2.4 m/s higher than the lowest closing velocity of the hood.*

A screening of possible test procedures, to be used for validation of the closure during an abusive slam, was conducted and the current procedure was evaluated with the use of high speed video equipment. The result revealed that the current procedure is accurate. Since no affordable method, conceived during the screening, was better than the one currently used it was kept and modified with the remark that if the test result is ambiguous or if it is needed to visualize the movement of the hood at a specific location high speed filming can be used.

The measurements for the correlation with the simulation models were performed both on a Saab 9-3 and on a rig car. Accelerometers were used at ten different locations of the hood, attaching parts and the body to visualize the movement of the system. This resulted in two sets of measurement files sent to the simulation department for correlation with the simulation models.
Preface

This degree project comprises the last ten weeks of the mechanical engineering education at the University of Trollhättan/Uddevalla. It was conducted at Saab Automobile AB in Trollhättan. I would like to thank my advisors Anna Runnemalm, at Saab and John Lorentzon, at the University of Trollhättan/Uddevalla. I would also like to express my appreciation to the people involved for their help and support.

Trollhättan, April 15, 2005

Robert Engberg
Contents

Summary.............................................................................................................................i
Preface .............................................................................................................................. ii
List of symbols .................................................................................................................iv
1 Introduction...................................................................................................................1
  1.1 Company presentation...........................................................................................1
  1.2 Background............................................................................................................1
  1.3 Problem description...............................................................................................2
  1.4 Purpose and significance.......................................................................................2
  1.5 Demarcation ..........................................................................................................3
2 Methodology.................................................................................................................3
  2.1 Studies of an abusive slam.....................................................................................3
  2.2 Screening and evaluation of test procedures for validation..................................5
  2.3 Conducting measurements for correlation with the simulation models ...............8
  2.4 Correlation with the simulation models ..............................................................11
3 Results.........................................................................................................................11
  3.1 Definition and requirement..................................................................................11
  3.2 Test procedure for validation ..............................................................................13
  3.3 Measurements for correlation with the simulation models .................................14
4 Conclusions.................................................................................................................15
  4.1 Conclusion of the gathered data..........................................................................15
  4.2 Conclusion about the definition...........................................................................15
  4.3 Conclusion about the test procedure ...................................................................16
  4.4 Recommendations for further work .................................................................16
References .......................................................................................................................17

Appendices

A Magnitudes
B Technical data on engine hoods
C Puma measurement technique
D CMM/DMM information from Krypton International
List of symbols

Closures – The subsystems door, hood, decklid and liftgate

GM – General Motors

GME – General Motors Europe

GM-NAO – General Motors North American Organisation

MY – Model Year

RLM – Road Lab Math – A continues project at GM and Saab to move tests from the Road into the Lab and ultimately into a virtual environment, Math

SSTS – Sub System Technical Specification – A requirement specification for a sub system

TDC – Technical Development Centre
1 Introduction

1.1 Company presentation

Saab Automobile AB is an automotive manufacturer owned by General Motors. It is a global brand and exports its cars all over the world. The cars are visualized in figure 1.1.1. The company conducts most of its technical development in Trollhättan where the main manufacturing plant is located. This degree project was conducted at the Technical Development Centre, TDC, in Trollhättan where design, simulation and testing are located. TDC is divided into units responsible for the design and validation of the body (TK), the chassis (TI), the electronics (TL), the interior (TF) and the complete vehicle (TV). All of these units are divided into sections. TKV is the section responsible for validation, testing and simulation of the body and exterior and is the section at which this degree project was performed.

![Figure 1.1.1: The Saab model range during 2005 incorporates the: 9-3 SportSedan, 9-3 SportCombi, 9-3 Convertible, 9-5 Sedan, 9-5 Combi, 9-2x and 9-7x](image)

1.2 Background

When closing a closure the closure will have some over travel before re-bouncing to its nominal position, which is the closed position of the hood. This is both due to the design of the latch, which needs some over travel for it to lock and the seal, which is retarding the closure during the over travel. An example of the hood latch’s need for over travel is shown in Figure 1.2.1. It is showing the hood latch on the Saab 9-3 at two different positions. In the left figure the hood lock spring is going to be pushed aside by the retaining pin. When the hood over travels the hood lock spring can return to its nominal position locking the hood when it re-bounces, which is displayed in the figure to the right.

Over travel is defined by the distance that the closure moves into the sealing plane, from its nominal closed position, during closing. When the closure has reached its maximum over travel distance it re-bounces to its nominal position. Even at the lowest closing...
velocity, which is defined as the lowest rim velocity needed for the latch to lock, the
closure will over travel. A higher closing velocity generates more over travel. The
critical closing velocity is defined as the maximum closing velocity permitted to be used
without any damages occurring on the closure, attaching parts or paint. When closing
with this critical closing velocity the closing event is referred to as an abusive slam.

Figure 1.2.1: The hood latch on the Saab 9-3 just prior to closing to the left and in the
locked position after closing to the right. Note that not all components are present for
easier visualization.

1.3 Problem description
An appropriate and customer related definition for an abusive slam on a vehicle hood
does not exist. Consequently the requirement is not customer related neither. It is
essential that the requirement specified in the requirement specification, SSTS, is
customer related to give the design department the correct knowledge of how customers
close the hood of the vehicle so that they can design the hood and attaching parts to
withstand an abusive slam without any damages occurring. The simulation and the
testing department perform their simulations and tests according to the SSTS and it is
also important that they perform their simulations and tests according to a customer
related requirement.

1.4 Purpose and significance
The purpose of this project is to propose a definition for what an abusive slam is. The
borderline between a normal closure and an abusive slam requires a specified limit. A
requirement for the closing of the hood is to be proposed. Furthermore a screening of
possible test procedures to be used for the validation of the hood during the abusive
slam test is to be conducted and the test procedure currently used is to be evaluated. If it
is found that the current procedure is not appropriate it is to be adjusted or replaced with one conceived during the screening. Data on the movement of the hood during an abusive slam is to be gathered. The data is to be used for correlation with the simulation models. The project will result in a definition and a requirement for the closing of the hood. It will also result in a test procedure and gathered data on the abusive slam of the hood.

Even though damages occurring on the hood or the attaching parts due to an abusive slam have not been a problem for several years\(^1\), the content of this degree project is significant for the design of future engine hoods so that damages will not occur when a customer closes the hood.

### 1.5 Demarcation

Abusive slam occurs for all closure systems, like doors, hoods and lids. The scope of this degree work is limited to the hood. Furthermore it is limited to hood systems utilizing gas struts as lifting aids. Although this work is focusing on the hood the information gathered can be applied to the other closure systems.

### 2 Methodology

The methodology of the project has been conducting studies of an abusive slam, conducting a screening for possible test procedures for the validation of the abusive slam test, evaluating the current test procedure and collecting measurement data about the acceleration of the hood and attaching parts during an abusive slam.

#### 2.1 Studies of an abusive slam

##### 2.1.1 Magnitudes

Several different magnitudes are possible to use when discussing the closing of vehicle closures; rim velocity, angular velocity, energy at a specific location, energy applied during the whole closing process and retardation. The magnitude used at GM is the rim velocity, which was also used in this project. For pros and cons about these different magnitudes see appendix A.

##### 2.1.2 Closing events

A set of different closing events was conceived through brainstorming. These different events were categorised into normal and not normal closing events. Included in the normal events were closing by a careful customer, closing by an average customer and closing by a rough customer. Included in the not normal closing events were the closing

\(^1\) Christer Hedlund, Cross Current Engineering, Customers Satisfaction & Quality, Saab Automobile AB
by a very rough customer, who closes the hood with a very high closing velocity. The other closing events, which were regarded as not normal, were when an object is located in the path of the closing hood, for example a tool forgotten on the radiator member or if the lifting aid malfunctions so the hood falls down. During discussions with the design department whether or not to include these not normal closing events in the requirement specification and developing a test procedure for them it was decided not to incorporate the event where an object is located in the path of the closing hood. Nor is the event where the lifting aid malfunctions to be included.

Due to the design of a hood latch it is not possible to close the hood with the latch in a locked position, see figure 1.2.1. This is possible with the design of the latches on the other closures, which have a latch and a striker. With the latter design the latch can be in the locked position during a closure resulting in a very high impact force on the fork in the latch and the striker, see figure 2.1.2.1. The design of the latch currently used on the hood, visualized in figure 1.2.1, has been the one incorporated in this thesis. If the hood will have another type of latch system in the future were a closure is possible with the latch locked this event must be assessed.

Figure 2.1.2.1: The door latch on the Saab 9-3 with the fork in the locked position while closing.

2.1.3 Gathering of information

The gathering of information about how customers close the hood of their vehicles was conducted by studying data received from studies performed by GM on customer cars and studying a customer clinic conducted earlier at TDC. Two customer clinics were also performed in-house at TDC and are incorporated in this thesis. Relevant technical data on these hoods is located in appendix B.
2.1.3.1 GM study on customer cars

To gather information about how customers utilize their vehicles GM has a measurement program where a set of vehicles is equipped with measurement devices. These data acquisition devices gather data about how customers use their vehicles. This program is called Product Usage Measurements and Applications (PUMA). The parameters, which are going to be measured, differ between programs. In the “1998 W Car Customer Vehicle Usage Measurement Program” [Webb 2003] data on closing occurrences versus closing velocity was gathered. This data show how many times the customer close the closures of the vehicles within pre-determined closing velocity intervals. These statistics are normalised to a specified distance of vehicle operation making it possible for the comparison of data. The data gathered about the closing velocities on the hood showed that no closing event had occurred at a higher closing velocity than 3.6 m/s. For more detailed information about the measurement technique and uncertainty, regarding hood closing velocity, in the puma data see appendix C.

2.1.3.2 Hood closing clinics

A clinic with seven of the employees at Saab was conducted in August 2004 showing that a normal closing of a Saab 9-5 MY2003 hood is between 1.5 m/s and 2.2 m/s with an average of 1.7 m/s [Olsson 2004].

Two clinics were performed by inviting employees at TK to close the hoods of the vehicles. The people closing the different hoods were told to close them as if they where stressed or angry but still as they would do on their own vehicle. This since the amount of people was very limited for conducting a clinic where the participants would not be told anything but to close the hood. The purpose of these two clinics was to gather information about at what closing velocity the “worst” customer would close a hood and this customer would probably be missed if the participants were not told to do this. The set up was first performed on a Saab 9-3 MY2005, then on a Saab 9-5 MY2004 since only one optical velocity meter needed for the clinics was available. During the clinic conducted on the Saab 9-3 fifteen people closed the hood five times each, resulting in a total of 75 measurements. Three of these were regarded as not valid since they were not conducted in a proper way. The clinic conducted on a Saab 9-5 included 33 participants who closed the hood five times each which resulted in 165 measurements.

2.2 Screening and evaluation of test procedures for validation

The purpose of the test procedure is to specify how to perform a test to validate the requirement for the abusive slam. The test is divided into two steps:

1. Measuring the over travel of the hood, in millimetres, at the different locations where contact can occur.

2. Checking that no damage occurs on the hood, attaching parts or paint.
2.2.1 Screening for possible test procedures

To determine the over travel of the hood different techniques can be used. Four techniques are presented here.

The test procedure currently used by GME, including Saab Automobile AB, is to make use of a plasticine material in the shape of cones positioned at the locations of interest for evaluating the over travel. In this procedure cones of plasticine are located where contact is a possibility, i.e. on the headlights, grille and on the flanges of the front wings. When the hood is subjected to an abusive slam these cones will be compressed to the height they get when the hood has its maximum over travel and stay in this position when the hood is opened. The difference in height of the plasticine cones before and after the slam is the over travel of the hood, $H_X$ in figure 2.2.1.1. This is an easy and non-destructive test procedure, which can be applied to all vehicles.

![Figure 2.2.1.1: The plasticine cones used in the current test procedure.](image)

$H_B$ Cone height before test
$H_0$ Nominal seal play
$H_V$ Cone height after test
$H_X$ Distance of over travel

An alternative to this is position sensors using laser but they require drilling of holes so that they can be positioned underneath the hood at the positions specified, since the space between the attaching parts and the hood is limited. This is not wanted since non-destructive testing is a requirement for the procedure.

Another alternative test procedure is to use a Coordinate Measurement Machine, CMM. Combined with a dynamic package allowing high frequency measurements it is possible to measure the movement of the hood relative the car during an abusive slam. This combination is referred to as a Dynamic Measurement Machine, DMM. It is a system utilizing infra red markers fastened on the hood of the car and on the attaching parts. The positions of these markers are registered by a camera and the relative distance between the hood and the attaching parts is calculated, see figure 2.2.1.2 [Krypton International 2005]. The software also calculates the over travel and the closing speed. This is a non-destructive way of testing, which can be used at several positions at a time, see appendix D. The drawback is that the equipment is expensive.

![Figure 2.2.1.2: A DMM used to measure the position of a door.](image)

---

2 Anna Runnemalm, Testing Lights and Mechanics, Saab Automobile AB
The third alternative is to use high speed filming and a graduated steel straight edge to visualize how much the hood will over travel. Due to the limited amount of space within the engine compartment filming is only possible outside this compartment. It is also only possible to film at one position at a time.

All of the possible test procedures mentioned above measures the over travel and have to be combined with a visual inspection of the tested closure, attaching parts and paint so that no damages have occurred during the slam.

2.2.2 Evaluation of the current test procedure

The results delivered when testing with the current test procedure had to be evaluated. This because the measurement uncertainty in this test procedure was unknown. There was a possibility that the cones would re-bounce a small distance when the hood is re-bouncing resulting in the measuring of the cones not showing the correct value of over travel. A better understanding of this phenomenon was therefore required and an investigation about it was conducted.

The evaluation of the test procedure was conducted using a high speed video camera recording 2 000 frames per second. This camera was filming the hood and a graduated steel straight edge at the location of a plasticine cone. The steel straight edge was mounted onto the front wing of the car giving the relative over travel of the hood compared to the front wing. This is the information of interest during the test. When the hood was closed the distance of over travel was determined both using the steel straight edge, on the movie clip, and by measuring the height of the plasticine cone as described in the test procedure.

Figure 2.2.2.1: The high speed video equipment used to evaluate the test procedure.
2.3 Conducting measurements for correlation with the simulation models

To be able to simulate the closing of the hood in a virtual environment data about the movement of the hood and the attaching parts are needed. This data was gathered by mounting accelerometers at different locations on the hood, grille and headlights.

2.3.1 Measurement system

The measurement system used for the data acquisition was the Pimento system from LMS. In the configuration used at Saab this is a sixteen-channel data acquisition device with a capability of sampling at 50 kHz. The sample rate was set to 25 kHz during these measurements so that no acceleration peak would be missed during the abusive slam.

2.3.2 Synchronizing the velocity meter with the measurement system

It was a request from the simulation department to be able to synchronize the optical velocity meter with the signal from the accelerometers to know at what time, during the closure, the velocity of the hood was recorded. Since it was not possible to connect the velocity meter to the measurement system another solution had to be made. An optical breaker was available and a trig box, which was compatible with the measurement system, was manufactured. With this optical breaker it was also possible to record at what time the hood was located in its nominal position, which was desirable at the simulation department. By recording at what time, during the measurement, the hood was located at the position where its velocity was recorded and it was in the nominal position it was possible to visualize this directly in the acceleration graph, without integrating the acceleration to derive the displacement.

For this reason a two-pin fork was mounted on the front edge of the hood and the optical breaker was mounted on a tripod in front of this edge. When each pin on the fork intersected the optical beam the beam was refracted, which resulted in an output signal. The set up was adjusted so that these pins intersected the beam when the hood was located in the desired positions. Since this system was compatible with the Pimento the output signal was synchronized in time with the signals from the accelerometers.

2.3.3 The accelerometer

The accelerometers used were piezoelectric, shear mode accelerometers. The design of the one-dimensional type of these accelerometers is displayed in figure 2.3.3.1 [PCB Piezotronics 2005]. The working principle is that a piezoelectric material, in this case a ceramic, is fastened between a centre post and a seismic mass. When the accelerometer is accelerated,
upwards or downwards in the figure, shear forces will be applied to the piezoelectric material. An electric charge is then generated between the two surfaces of the material. This charge is transformed into a voltage which is compatible with a measurement system such as the Pimento. This transformation is accomplished either by an ICP, Integrated Circuit Preamplifier, or an external charge amplifier, see figure 2.3.3.2 [PCB Piezotronics 2005].

Figure 2.3.3.2: The accelerometer with an internal circuit preamplifier directly connected to the measurement system is displayed to the left and the accelerometer connected to the measurement system via a charge amplifier is displayed to the right.

2.3.4 The measurement set up

For the visualization of how the body of the car moves, during the closing of the hood, two accelerometers were mounted on the right front rail. By knowing the position of these accelerometers and most essentially their relative distance from each other in the x-direction, see figure 2.3.4.1, it is possible to determine the movement of the front rail and consequently the whole body of the car.

Figure 2.3.4.1: The position of two of the accelerometers used and the main coordinate system of a vehicle. The x-axis runs in the longitudinal direction of the car, the y-axis in the transverse direction of the car with its origin in the centre line of the car and the z-axis runs in the elevation of the car. [Carlson 2004]
The four accelerometers used on the front rail, on the rear edge and centre of the hood were three-dimensional accelerometers with integrated circuit preamplifiers. They had a maximum operational level of $500 \, \text{m/s}^2$ and a frequency range of 6 kHz. Only the z-axis of these accelerometers was used since no information about the movement in the x- and y-direction was necessary for the simulation models.

A maximum operational level of $500 \, \text{m/s}^2$ was not enough on the other six locations, the front edge of the hood and the attaching parts, during an abusive slam. The acceleration at these positions exceeds this level at a quite low closing velocity. This since the hood of the car is not a well-damped system. The hood has only a front and rear weather seal combined with rubber bump stops to damp the system. Since no accelerometers, with integrated circuit preamplifiers which had a higher maximum operational level, were available accelerometers with external charge amplifiers had to be used. These accelerometers were one-dimensional accelerometers with a maximum operational level of $50 \, 000 \, \text{m/s}^2$ and a frequency range of 16 kHz. The sample rate set at 25 kHz in the Pimento was the lowest possible above 16 kHz, which was the maximum frequency range of the accelerometers used. The measurement set up on the Saab 9-3 is visualized in figure 2.3.4.2.

A position sensor was used to correlate the displacement values derived from the accelerometers positioned on the front rail. This was a cable extension position transducer mounted between the ground and the subframe.

![Figure 2.3.4.2: The measurement set up showing the accelerometers on the hood and the attaching parts, the Pimento measurement system, pc and charge amplifiers on the table and the velocity meter and optical breaker in front of the car.](image)
2.3.5 Measurements conducted on the Saab 9-3

Before the measurements for correlation with the simulation models could commence, the hood was measured and adjusted according to the standard for fit and flush and the seal play was then determined. The measurements were conducted in four steps. First without any modification of the car, then a component was removed before each of the following tests. The components removed were the gas strut, the bump stops and the hood latches. This made it possible for the simulation department to see how significant each of the components is for the movement of the hood during the abusive slam.

2.3.6 Measurements conducted on the rig car

The difference between the measurements on the Saab 9-3 and the rig car was that the measurements on the rig car were conducted with three different configurations for the front weather seal, instead of removing components. This since the effect of the weather seal was most significant both for the simulation model for the rig car and the design department.

2.4 Correlation with the simulation models

The measurement files were transformed into the ASCII format when exported from Pimento so that they could be used in HyperGraph at the simulation department. In HyperGraph the acceleration values are to be integrated into velocity and displacement values. The values obtained are to be correlated with the values in the simulation models making it possible to update the simulation models if necessary.

3 Results

This degree project has resulted in a definition and a requirement for an abusive slam. It has also resulted in a modification of the current test procedure and 61 measurement files to be used for correlation with the simulation models.

3.1 Definition and requirement

3.1.1 Closing event to be used in the definition

The only closing event to be incorporated in the definition of an abusive slam is when closing the hood with a high velocity. The requirement is preferably expressed as a constant velocity added to the lowest closing velocity of the hood.

3.1.2 Results from the clinics

The graph visualized in figure 3.1.2.1 is the result from the clinic conducted on the Saab 9-3. The closing velocity ranged between 1.34-3.97 m/s with an average of 2.44 m/s. The lowest closing velocity of the hood in this test was 1.20 m/s.
Abusive Slam on a Car Hood

The result from the clinic conducted on the Saab 9-5 is visualized in figure 3.1.2.2. The closing velocity here ranged between 1.24-3.91 m/s with an average of 2.15 m/s while the lowest closing velocity was 1.10 m/s.

Figure 3.1.2.2: Number of closing events vs. closing velocity intervals for the 9-5 hood with a total of 165 closing events.
A study of the data gathered from the clinics revealed that 97.2% of the closures of the hood on the 9-3 occurred at a lower closing velocity than 3.56 m/s and 99.4% of the closures of the hood on the 9-5 occurred at a lower closing velocity than 3.45 m/s. These velocities were regarded as the velocities the “worst” customer might achieve. 3.6 m/s for the hood on the 9-3 and 3.5 m/s for the hood on the 9-5 are 2.4 m/s above the lowest closing velocity for each vehicle.

3.1.3 Definition of the abusive slam

Abusive slam is defined as a closing of the hood with the critical closing velocity. The critical closing velocity is proposed to be 2.4 m/s higher than the lowest closing velocity of the hood.

3.1.4 Requirement for the abusive slam

The requirement is that the hood, the attaching parts and the paint shall be able to withstand a closure with a velocity of 2.4 m/s added to the lowest closing velocity of the hood, without any damages occurring.

3.2 Test procedure for validation

3.2.1 Results from the evaluation of the test procedure

The test conducted to evaluate the current test procedure, for the validation of the closure during an abusive slam test, resulted in a small difference in over travel when measuring as specified in the test procedure and when measuring with the steel straight edge visualized with the high speed video camera. The measured values with the plasticine cones were by enlarge lower than the values visualized on the movie clips. The difference between the over travel values measured with the plasticine cones and the values from the high speed filming had an average of -0.17 mm. This is visualized in table 3.2.1.1 where the hood is closed at different velocities during closure 1-10.

<table>
<thead>
<tr>
<th>Closure</th>
<th>Over travel measured with the plasticine cone [mm]</th>
<th>Over travel measured with the high speed camera [mm]</th>
<th>Difference</th>
<th>Difference [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.23</td>
<td>2.4</td>
<td>-0.17</td>
<td>-7.1</td>
</tr>
<tr>
<td>2</td>
<td>3.26</td>
<td>3.1</td>
<td>+0.16</td>
<td>+5.2</td>
</tr>
<tr>
<td>3</td>
<td>3.09</td>
<td>3.3</td>
<td>-0.21</td>
<td>-6.4</td>
</tr>
<tr>
<td>4</td>
<td>2.76</td>
<td>3.2</td>
<td>-0.44</td>
<td>-13.8</td>
</tr>
<tr>
<td>5</td>
<td>2.88</td>
<td>3.0</td>
<td>-0.12</td>
<td>-4.0</td>
</tr>
<tr>
<td>6</td>
<td>2.48</td>
<td>2.8</td>
<td>-0.32</td>
<td>-11.4</td>
</tr>
<tr>
<td>7</td>
<td>2.22</td>
<td>2.5</td>
<td>-0.28</td>
<td>-11.2</td>
</tr>
<tr>
<td>8</td>
<td>2.10</td>
<td>2.2</td>
<td>-0.10</td>
<td>-4.5</td>
</tr>
<tr>
<td>9</td>
<td>2.80</td>
<td>2.9</td>
<td>-0.10</td>
<td>-3.4</td>
</tr>
<tr>
<td>10</td>
<td>2.48</td>
<td>2.6</td>
<td>-0.12</td>
<td>-4.6</td>
</tr>
</tbody>
</table>

Table 3.2.1.1: The test results from the comparison.
3.2.2 Test procedure to be used

It has been decided to use the current test procedure, utilizing the plasticine material, to determine the over travel of the hood. This test procedure is the least expensive and is easy to use still giving accurate results. However the test procedure has been modified with the remark that if the result from the test is ambiguous or if contact occurs and it is desirable to visualize the test high speed filming can be used as a complement to the ordinary test procedure.

3.3 Measurements for correlation with the simulation models

The measurements conducted on the hood of the Saab 9-3 and the rig car resulted in 32 and 29 measurement files respectively, to be used for correlation with the simulation models. These files contain the acceleration at ten positions on the hood, the attaching parts and on the front rail. The position change of the subframe is also included. Two internal reports were also written to accompany these files [Engberg 2005]. The hood has been closed at several different velocities including the velocity specified in the definition of the abusive slam to generate these measurement files. Figure 3.3.1 is visualizing an example of the measurements showing the acceleration curves of the hood and the front facia of the rig car, in blue and red. The hood is in the location where its velocity is recorded at the first high level of the purple curve. During the following two high levels of the same curve the hood is in its nominal position.

![Figure 3.3.1: The blue curve is visualizing the acceleration of the hood at a specified location whilst the red curve is showing the acceleration of the front facia in the proximity of the measured point on the hood. The signals are unfiltered.](image-url)
4 Conclusions

4.1 Conclusion of the gathered data
Engineering judgement of the hood closing clinics combined with the guidance from the puma data, on the interval of the highest closing velocity, generated a reasonable definition and requirement for the abusive slam.

4.1.1 The clinics
The clinics were conducted in-house at Saab TDC, with Saab employees. This could have been a problem if the participants worked with or were familiar with hood closures. Then they probably would have had the knowledge about how a hood should be closed in a “correct” way. This was not the case for most of these participants. They had many different techniques for the closing of the hood, like the customers have.

The most realistic results from the clinics would have been achieved if the participants were not told anything but to close the hood of the vehicle. But this would have required hundreds of participants to get a realistic result, since the purpose of these clinics were to find out at what velocity the “worst” customer would close the hood.

The highest closing velocities, achieved during the clinics, were regarded as too rough to be included in the definition and the requirement specification. If a customer would close the hood with these velocities it was judged that he or she would have to accept the possible consequences.

4.1.2 The puma data
Since the puma data about the closing velocities of the hood is only available as overall combined statistics for 20 vehicles and statistics for each individual vehicle is not available it will just give a hint at which interval the 99.8 percentile customer would close the hood. Furthermore the highest velocity interval in the puma data, between 3.4 and 3.6 m/s, measured by the set-up in the set of vehicles is comparable to a hood rim velocity in the range 3.1-4.0 m/s measured by the optical Debron velocity indicator used during testing in the lab environment. This is due to the different measurement techniques and the measurement uncertainty discussed in appendix C. However no closing event during the three year study of these 20 vehicles occurred at a higher velocity than 4.0 m/s.

4.2 Conclusion about the definition
When defining the critical closing velocity as a constant value added to the lowest closing velocity a hood that has a relatively high lowest closing velocity gets a somewhat higher critical closing velocity and vice versa. The purpose of this is to take into account if the hood is perceived as it is difficult to close by the customer. If so the
risk of a customer closing it with an even higher closing velocity is higher than if it is perceived as easy to close.

However the difference in the lowest closing velocity is relatively small comparing individual cars making it possible to set a specified value, for the critical closing velocity, during a project based on a result from a simulation or a test.

The requirement that a hood and its attaching parts should be able to withstand a closure with the critical closing velocity described above without any damages occurring is a more challenging requirement than the requirements previously used. The advantage of the new requirement proposal is that it will ensure that the hood and the attaching parts will be able to be used by a higher percentile of customers without damages occurring.

4.3 Conclusion about the test procedure

It has been concluded that the current test procedure for validating the closure during an abusive slam test is the most cost effective still giving accurate results. It can be used on any vehicle and requires no permanent modifications to be made on the vehicle.

The disadvantage of utilizing this test procedure is that the measured over travel is somewhat lower than the actual over travel. It has been concluded that the cones do not re-bounce, as discussed in chapter 2.2.2. The reason for the lower values is that the hood has to be closed before the abusive slam to measure the nominal seal play, $H_0$ in figure 2.2.1.1. When closing the hood very carefully it still will over travel a small distance so the latches can lock. This over travel distance is therefore not included in the over travel specified as $H_X$ in figure 2.2.1.1.

4.4 Recommendations for further work

Since this degree work is a part of a Road Lab Math, RLM, project the work still left is the correlation between the data gathered and the simulation models. This work is to be performed by the simulation department. When this correlation has been completed, test simulations are to be conducted and further correlation with another individual car is needed to verify the validity of the simulation models.

A more thorough investigation about utilizing the Dynamic Measurement Machine in the test procedure is recommended when it is economically possible to purchase such a machine. This would replace the use of the plasticine material, in the current test procedure, and would result in an even more accurate measurement. It would also yield a more effective correlation between simulation and testing.
References


A Magnitudes

Rim velocity
Advantages:

- Easy to measure
- There are customer data available
- Does not depend on the characteristics of the system, i.e. the mass
- The velocity meter used at GM is available at Saab
- Good repeatability
- Relatively small scatter

Disadvantages:

- Depending on the length of the system

Angular velocity
Advantages:

- Does not depend on the characteristics of the system, i.e. the mass
- Easy to calculate, in a point, from the measurement of the rim velocity \( \omega = \frac{v}{l} \)
- Good repeatability
- Relatively small scatter

Disadvantages:

- More difficult to measure directly

Energy at a specific point
Advantages:

- Easy to calculate from the measurement of the rim velocity \( E = \frac{1}{2}(I*\omega^2) \) if knowing the moment of inertia, I.
- It is possible to compare different closures.

Disadvantages:

- Relatively large scatter according to an earlier report on customer clinics [Mabäcker, Ågren, Östan 2001]
Energy during the whole closure

Advantages:
- An advanced method, which takes most parameters into consideration.
- It is possible to compare different closures.

Disadvantages:
- Difficult to measure since both the applied force and the angular velocity is needed
- Requires data about how customers close their closures, which is not available
- Not so good repeatability

Retardation

Advantages:
- Relatively easy to measure
- The accelerometers can be located on the vehicle during a durability test

Disadvantages:
- Large scatter according to an earlier report on customer clinics [Mabäcker, Ågren, Östan 2001]
- Depends on the concept of seal used etc
B  Technical data on engine hoods

Saab 9-3 MY 2003-
Material: Aluminium
Total mass: 10.0 kg
Lift aid: One gas strut
Distance between pivot centre and front edge: 1239 mm

Saab 9-5 MY 1998-
Material: Steel
Total mass: 24.5 kg
Lift aid: Two gas struts
Distance between pivot centre and front edge: 1269 mm

The rig car
Material: Steel
Total mass: 26.1 kg
Lift aid: Two gas struts
Distance between pivot centre and front edge: 1339 mm

“W”-car MY1998 used in the puma data
Material: Steel
Total mass: 17.7 kg
Lift aid: Two gas struts
C  Puma measurement technique

In the “1998 W Car Customer Vehicle Usage Measurement Program” data was gathered about the closing velocity of the hood.

**Puma measurement technique for closing velocity**

The measurement technique used on the “W”-car to measure the closing velocity of the hoods consisted of a data acquisition unit, with a sample rate of 500 Hz, and two different switches set to trip at different points during the hood travel. The first switch was set to trip when the front edge of the hood was 120 mm from its nominal closed position and the second switch was set to trip when the secondary hood latch latched. An average closing velocity over the 120 mm of hood travel was then calculated and stored.

**Comparison between the puma measurement technique and an optical velocity meter**

Since the velocity measured in the puma data is an average velocity over 120 mm of hood travel including weather seal contact and hood latch contact it is not directly comparable to the Debron optical closing velocity meter currently used by both GM-NAO and Saab Automobile AB. This optical closing velocity meter calculates an average closing velocity during 12.7 mm of hood travel just prior to weather seal contact.

**Puma measurement uncertainty**

The measurement uncertainty was rather great at high closing velocities. This was due to two different major aspects. The data acquisition sample rate is only 500 Hz resulting in a data acquisition interval of 2 ms and the distance at which the measurement occurred varied between 112.5 and 127.5 mm where the intended interval should have been 120 mm.
Appendix D

CMM/DMM information from Krypton International

Application note

Car body Closures

Complete door closure analysis with the K600 system

Measure all the important static and dynamic parameters of a car door with one system: seal gap, over-slam, drop-off, closing speed, closing deformation, ...

Avoid complex fixing mechanisms for finished cars: the K600 measures "cars on wheels".

Reduce measurement time: stick some infrared markers on the car and you’re ready to measure.

Visualize the closing process for better understanding of possible problems.

Application

When a customer approaches a new car, his first impression of the car will be based on his first point of contact with the car: the car door. As we only get one chance to make that first impression a good one, the behavior of the door is regarded as one of the most important issues when designing a new car. Huge amounts of time and effort are put into tuning the production line to make a door that closes smoothly without generating too much wind noise while driving.

The behavior of a car door is defined by the interaction of a lot of parameters: over-slam, drop-off, closing speed, seal gap, dimensional correctness, bumper compression, closing deformation, striker-pin fit, hinge axis location, ... The optimal values for these parameters are usually known. The main problem here however, is checking whether these values are really achieved on the finished car. Measuring these parameters is often very time consuming, requires a lot of different and often complex to use tools and requires quite some experience of the operator to interpret the results. In some cases measurements are even impossible with traditional tools. A simple example, the seal gap, which is the gap between the door and the chassis: this gap has to be measured with the door in closed position but in this position the gap is not accessible for any measurement device.

The K600 measurement system however has some very unique features that make it the ideal system for this kind of analysis. The possibility to do static as well as dynamic measurements, the very easy and fast set-up of the system, the patented “dynamic reference” that can measure moving objects as if they were static, 2D and 3D visualization of the results are all features that are highly valued by everyone that is involved with door closure analysis.

K600: The measurement system

The K600 system is a camera based co-ordinate measurement machine. The system is composed out of 3 linear CCD units of 2048 pixels. The system is pre-calibrated and traceable back to a primary standard. The sensor captures the infrared light emitted by diodes called markers. Using triangulation, the 3D position of one or more markers is calculated.

The Space(r) Probe, equipped with these markers, is used to measure...
Abusive Slam on a Car Hood

Appendix D:2

point points. The operator holds the Space Probe in his hand and positions the probe tip on the object. The X, Y and Z co-ordinates of the probe tip are measured in real time with high accuracy. Different probe tips of all sizes and shapes can be used on the probe to have access to hidden points. The buttons on the probe allow the operator to trigger certain software functions from the Space Probe. The indicators on the probe give information concerning visibility and measurement information.

K600: A toolbox for CMM, DMM and Robotics

Initially the principle of markers and camera was successfully used to calibrate industrial robots in the most difficult environments. Through the years new applications for this principle emerged.

The development of the Space Probe and the K-CMM software allowed the acquisition of static 3D points. The K-CMM software can send these coordinates to any of the most popular software packages available for geometric measurements, CAD comparison or reverse engineering.

Instead of tracking the robot's motion, the markers can also be used to track the GD motion (translation and rotation) of other objects: the DMM application! The K600 system measures the motion of the object and the DMM software will calculate the path, speed, acceleration, overshot, ... of these objects.

Features

- High accuracy and wide measurement range
- Maximum sampling rate: 2490 Hz
- On-line feedback
- Measurement volume: 1m x 1.2m at 2.5m distance going up to 2.8m x 3.6m at 6m distance
- 100% Mobile and stand alone
- Fast set up
- Windows 2000 and XP compatible

Door closures analysis application

Measurement setup

Setting up the K-600 camera system for door closure analysis is very easy: the operator starts by attaching some infrared markers on the car and the chassis. These markers will serve a dual purpose:
- Compensate for any movement of the car while doing static measurements (i.e. when getting in to the car, it will move because of the suspension).
- Measure the GD motion of the door relative to the chassis.

Next the operator puts the camera in front of the car so that all the infrared markers are in the field of view of the camera. Thanks to the large field of view of the K-600 camera an entire side of a car can be measured with a single camera position. Now the measurements can start.

Static measurements

For static measurements on the finished car the operator will use the Space Probe to measure discrete points on the door or the chassis. This way the position of holes, pins, slots, ... on the car can be identified very fast and accurate.

Here a powerful feature of the K600 system comes in handy: the Dynamic Reference. In conventional metrology the measurement object is not allowed to move while measuring it. Every movement of the measurement object or measurement device induces errors and the greater the movement, the greater the error. Not with the K600 system! The infrared markers attached to the car, track any movement of the car and a special software feature compensates for these movements. This means no special precautions need to be taken to ensure that the car doesn't move while measuring it: you simply measure the car on its wheels! But the possibilities reach even further thanks to the Dynamic Reference we can measure in places that are normally inaccessible for a measurement device. For example, measuring the seal gap with the door in closed position seemed impossible until now, but is very simple with the K-600 system. Both parts (door and chassis) can be measured with the door in opened position when they are easy accessible. The software will compensate online for the "opening-of-the-door" movement and the results will appear on the screen as if the door was in closed position.
The measurement software also allows you to import CAD data. So measurements taken on the car can immediately be compared with the nominal values found in the CAD file and deviations will be shown on line. This way it only takes you a couple of minutes before you know which part is causing problems.

All the results of these measurements are available as graphical and textual reports with just one click on the mouse.

**Dynamic measurements**

Where static measurements on car doors are common business in a metrology lab, dynamic measurements were still the privilege of a happy few. The reason for this was that dynamic measurements on a door could only be done with complex and expensive instruments, required a lot of time and a lot of experience and knowledge to interpret the results. The K-600 system now integrates an easy to use interface in a powerful measurement device for dynamic measurements. With the infrared markers attached to the car door and chassis, the motion of the door relative to the chassis can be tracked. The K-600 camera system will measure the position of the markers at a high rate (up to 1800 Hz with 3 markers) so the complete closing process of the door can be measured very accurately. With one simple measurement like this (which takes only as long as closing a door), an interesting set of parameters can be identified: over-slam, door drop or lift, closing speed, ... . Results are immediately available after the measurement and the various formats in which they are presented (spreadsheets, 2D graphs, 3D movies) make the analysis and reporting an easy job.

**Conclusion**

Thanks to some unique features the K-600 system is the ideal instrument to get fast and accurate results for analysis of the door closure process on a car.

* With the Space Probe you can quickly measure points on the car and see the deviations on-line.
* The Dynamic Reference enables measurements on a “car on wheels” and lets you measure in areas that are normally unreachable.
* The easy principle of attaching infrared markers to the object reduces set-up time drastically.
* The combination of static and dynamic measurements with one system lets you identify a complete set of parameters for door closure analysis: seal gap, door drop-off, stiker-pin position, closing speed, door over-slam, door deformation, ...
* The user-friendliness of the interface makes measurements and analysis simpler than ever.

**Other documents**

For more information, the following documents can be requested:

**Contact Krypton today**

[Contact information for Krypton]

Appendix D:3